AN EMISSION CONTROL SYSTEM AND A METHOD FOR OPERATING AN EMISSION CONTROL SYSTEM

FIELD OF THE INVENTION

The present invention relates to an emission control system, particularly for an automobile with an internal combustion engine, having a particle filter. The present invention also relates to a method for operating an emission control system.

BACKGROUND INFORMATION

Particle filters are used for diesel-operated vehicles to reduce particle emissions. Particle filters are primarily used to capture soot particles in the exhaust. Soot particles captured in the particle filter can be combusted in special operating phases of the internal combustion engine. However, ash residue in the filter cannot be combusted, which clogs the filter over the life of the vehicle.

The following ash components are generally responsible for clogging the filter: motor oil ash residue from the oil consumed by the internal combustion engine; fuel ash residue from fuel consumption; additive ash residue from fuel additives to help regenerate the particle filter; and other residue, e.g., from intake air, motor abrasion or wear, and corrosion of the exhaust system.

As a result, particle filters must be replaced or cleaned in a washing procedure after a given service interval, e.g., every 80,000 km traveled.

The clogging of the filter from ash is a continuous process over the life of the vehicle. With an average oil consumption of 0.2 l/1000 km, up to 180 grams ash or more can develop after 100,000 km. The ash residue in the filter causes increased pressure drop in the particle filter, which increases exhaust counterpressure, increases fuel consumption by 8% or more, and decreases engine power. Since the ash

residue cannot be decomposed or regenerated, the particle filter must be either removed and cleaned or replaced after a certain period or after a certain amount of ash has collected in the filter.

In particular, Ca, Fe, Mg, Zn, P and S develop in the exhaust from oil consumption. Sulfur develops in the exhaust from fuel consumption. Ce, Fe, Ca and Na enter the exhaust from fuel additives. Fe and Al enter the exhaust from abrasion and corrosion.

Ash forms from sulfates, oxides and phosphates, e.g., sulfate ash in the form of $CaSO_4$ and oxide ash in the form of CaO.

More than 50% of the resulting ash deposits in the filter are created by sulfate ash.

Figure 5 schematically illustrates a conventional emission control system with oxidation catalyst 1 and particle filter 2. The exhaust coming from the engine contains sulfur compounds, e.g., 98% SO_2, 2% SO_3 and Ca, Fe, Mg, Zn and P. At temperatures above 350°C, sulfate forms in oxidation catalyst 1, where SO_2 and SO_3 are converted into SO_4. Ash, such as $CaSO_4$, $ZNSO_4$, $MgSO_4$, CaO, FeO, etc., develops downstream from oxidation catalyst 1. This ash collects in particle filter 2 and clogs it.

SUMMARY

The present invention provides an emission control system and a method to operate an emission control system to reduce the clogging of the particle filter by ash residue.

According to the present invention, an emission control system, particularly for a motor vehicle having an internal combustion engine, is provided with a particle filter, and an arrangement is provided upstream from the particle filter to prevent ash-forming compounds of the sulfur in the exhaust from developing.

The present invention is based on the principle of preventing ash from developing in advance of the particle filter and transforming the compounds responsible for the ash

formation into a gaseous state or keeping them in a gaseous state so that they can flow through the particle filter without collecting. The objective is to avoid primarily sulfates, which represent a major component of the ash.

Accordingly, the sulfur in the exhaust, which is primarily responsible for the formation of ash, is converted into compounds that do not form ash in order to prevent sulfates from forming in the exhaust.

In one example embodiment of the present invention, the arrangement includes an SO_x collector.

By using an SO_x trap or SO_x collector, the sulfur contained in the exhaust may be stored to substantially reduce the amount of ash-forming sulfur compounds in the exhaust. When the storage capacity of the SO_x trap is exhausted, it may be regenerated in a regeneration phase. The stored sulfur is released in the form of gaseous compounds that may pass through the particle filter.

The arrangement may be combined with a NO_x collector and/or an oxidation catalyst.

These measures improve the quality of the exhaust.

The present invention also provides a method to operate an emission control system so that no ash-forming compounds develop from the sulfur contained in the exhaust.

The formation of ash may be substantially reduced in this manner, since sulfur compounds represent a large portion of the compounds responsible for ash formation.

In a further example embodiment of the present invention, there are normal operating phases with a lean exhaust composition for storing the sulfur contained in the exhaust, and there are regeneration phases with a rich exhaust composition to release the stored sulfur in the form of gaseous compounds.

During the normal operation phases, the formation of sulfate in the exhaust and accordingly the formation of sulfate ash are reduced. When the storage capacity of the sulfur collector is exhausted, a regeneration phase with a rich exhaust composition is initiated to regenerate the sulfur

collector. The stored sulfur is released in the form of gaseous compounds that may pass through the particle filter. This arrangement effectively prevents the filter from clogging due to ash. The service interval for cleaning or replacing a particle filter may be greatly increased with the same filter volume. The sulfur oxides in the exhaust, such as SO_2 and SO_3, are stored in the sulfur collector on a storage metal such as barium (Ba). Hence, $BaSO_4$ develops in the sulfur collector. This arrangement prevents the formation of sulfate in the exhaust downstream from the sulfur collector. During the regeneration phase, the $BaSO_4$ stored in the sulfur collector is converted to SO_2, H_2S and COS. There is little formation of SO_4 due to the low-oxygen or rich exhaust composition. The released sulfur compounds are gaseous and may therefore pass through the particle filter. After the sulfur collector is regenerated, the engine may be operated with a lean exhaust composition.

The exhaust temperature in the regeneration phase may be raised to 550-700°C.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of a first example embodiment of the emission control system according to the present invention.

Figure 2 is a schematic view of a second example embodiment of the emission control system according to the present invention.

Figure 3 is a schematic view of a third example embodiment of the emission control system according to the present invention.

Figure 4 is a schematic view of an exhaust system of an automobile with an internal combustion engine having an emission control system according to the present invention.

Figure 5 is a schematic view of a conventional emission control system.

DETAILED DESCRIPTION

Figure 1 schematically illustrates an emission control system according to the present invention with a SO_x collector 10 and particle filter 12. The exhaust passes via a pipe section 14 from an internal combustion engine to SO_x collector 10. The direction of flow in the emission control system is indicated by arrows. The sulfur compounds in the exhaust coming from the motor in pipe section 14 are approximately 98% SO_2 and approximately 2% SO_3. Ca, Fe, Mg, Zn and P are also contained in the exhaust.

SO_x collector 10 stores the sulfur oxides SO_2, SO_3 on a storage metal such as barium (Ba) when the exhaust composition is lean, a so-called hyperstoichiometric exhaust composition with $\lambda > 1$, in the form of $BaSO_4$. The formation of sulfate in the exhaust and subsequent formation of sulfate ash are accordingly reduced. The ash-forming components in the exhaust either react to form oxide ash or remain in a gaseous state. For example, Ca, Fe, Mg, Zn and P are present in pipe section 16 and particle filter 12 as gaseous compounds and may pass through them, which reduces the deposition of ash in the particle filter 12. Even when oxide ash forms instead of sulfate ash, the amount of ash in particle filter 12 may be reduced, since oxide ash has a lower molar mass than sulfate ash.

The internal combustion engine creating the exhaust may be operated with fuel containing less sulfur, e.g., less than 10 ppm, so that there will be a very small base load of sulfur in the exhaust. Even when sulfur-free fuel is used, SO_x collector 10 is useful since the exhaust in pipe section 14 contains sulfur components from consumed motor oil.

When the storage capacity of SO_x collector 10 is exhausted, a regeneration phase according to the present invention is started. The exhaust temperature is increased to 550-700°C to regenerate or desulfurize the collector, and the internal combustion engine is switched to hypostoichiometric operation or rich operation ($\lambda < 1$). In the regeneration phase, SO_x collector 10 releases the sulfur, stored as $BaSO_4$ in the form of gaseous sulfur compounds such as SO_3, SO_2, H_2S or

COS. There is little SO_4 formation due to the low-oxygen or rich air/fuel ratio. The released sulfur compounds may pass through particle filter 12 in a gaseous state. Even in the regeneration phase, sulfates do not form in pipe section 16, and Ca, Fe, Mg, Zn, P are present as gaseous compounds and may pass through particle filter 12 so that there is less ash deposition. After SO_x collector 10 is regenerated, the internal combustion engine may be operated with a hyperstoichiometric or lean exhaust composition.

Figure 2 schematically illustrates another example embodiment of the emission control system according to the present invention in which, in contrast to the emission control system illustrated in Figure 1, SO_x collector 10 is combined with NO_x collector 20.

Figure 3 illustrates a third example embodiment of the emission control system according to the present invention in which, in contrast to the emission control system illustrated in Figure 1, SO_x collector 10 is combined with NO_x collector 20 and an oxidation catalyst 22.

The emission control systems illustrated in Figures 2 and 3 further reduce pollutants in the exhaust. The emission control systems illustrated in Figures 2 and 3 are operated in the same manner as that illustrated in Figure 1, i.e., with normal operation phases having lean exhaust composition to store the sulfur in the exhaust in the form of sulfate, and, after the storage capacity of SO_x collector 10 is exhausted, with regeneration phases having a rich exhaust composition to release the stored sulfur in the form of gaseous compounds.

Figure 4 schematically illustrates a diesel engine 24 that includes an emission purification system according to the present invention. Diesel engine 24 is supplied with diesel fuel having a reduced sulfur content from a fuel tank 26. The fuel is injected with a so-called common-rail injection system 28. Diesel engine 24 is provided with an exhaust turbocharger 30 that supplies compressed intake air via charge-air cooler 32 to intake manifold 34 of diesel engine 24.

Between exhaust manifold 36 and intake manifold 34 is an exhaust return line 38 that may be opened and closed by controllable exhaust return valve 40.

Proceeding from the exhaust manifold 36, the exhaust from diesel engine 24 passes via the exhaust turbine of exhaust turbocharger 30 to a SO_x collector 42. SO_x collector 42 is combined with a NO_x collector and an oxidation catalyst. Downstream from SO_x collector 42 is a particle filter 44. The particle filter 44 is followed by an underbody catalyst that further reduces pollutant emissions. Downstream from the underbody catalyst is a muffler to reduce noise.

Controller 50 controls common rail injection system 28 and exhaust turbocharger 30 and may accordingly set a rich or lean exhaust composition. Exhaust return valve 40 is also controlled by controller 50. Sensors 52 are provided at several locations in the exhaust system that detect the current exhaust composition and send it to the controller 50. By analysis of the sensor signals in controller 50, the remaining storage capacity of SO_x collector 42, for example, may be inferred. If controller 50 determines that SO_x collector 42 is full, a regeneration phase is started. After SO_x collector 42 is regenerated, the controller 50 switches back to storage operation.